Language and Number Values: The Influence of the Explicitness of Number Names on Children's Understanding of Place Value

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Abstract :In recent years, the idea of language influencing the cognitive development of an understanding of place value has received increasing attention. This study explored the influence of using explicit number names on prekindergarten and kindergarten students' ability to rote count, read two-digit numerals, model two-digit numbers, and identify the place value of individual digits in two-digit numerals. Through individual student interviews, pre- and post-assessments were administered to evaluate rote counting, reading five two-digit numerals, modeling five two-digit numbers, and identifying place value in two two-digit numerals. Chi-square tests for independence showed two significant relations: (1) the relationship between the control and treatment group membership on the post-assessment of modeling two-digit numbers and (2) the relationship between place value identifications and group membership. Analysis of the children's performance and error patterns revealed interesting differences between children taught with explicit number names and children taught with traditional number names. The improvement of the treatment group overall exceeded the improvement of the control group. This study indicates that teaching children to use explicit number names can, indeed, have a positive influence on their understanding of place value.

Introduction

The superior performance of Chinese speaking countries in international tests in mathematics and science raises the question of what advantages there might be in the language itself. While many reasons for national differences in these tests can, should, and have been posited, the question of language advantage remains unanswered. A quantification of the number of words needed to name the numbers from one to one hundred was used to investigate correlation between this and position in national test rankings (Beauford, 2003). Languages considered were English, German, French, Spanish, Chinese, Japanese, and Korean. When learning to count to 100 in Mandarin Chinese, children use a total of 11 words. In English, the task requires 26 different words or word parts. Correlations were negative, strong, and significant. Almost without exception, the fewer words or word parts needed to name numbers to 100, the better was the position of the country in international comparison.

The question of whether language influences mathematics performance has prompted a progression of studies. Miura (1987), Miura and Okamoto (1989), Ginsburg (1989), Miura, Okamoto, Kim, Steere, and Fayol (1993), MacLean and Whitburn (1996), and Alsawaie (2004) compared children from different language heritages. These studies involved a single assessment of the mathematics performance of intact groups of students without intervention. Most of these studies were conducted in the United States comparing native English-speaking students with students whose native language was not English and who were attending classes taught in their native language. Fuson and Briars (1990), Fuson, Smith, and Cicero (1997), Fuson, et al. (1997), and Cotter (2000) conducted studies that applied and analyzed the results of using explicit number names for several months with first grade students.

Beauford (2003) extended the research further in an investigative study using explicit number names as an intervention with four- and five year-old students beginning their first formal introduction to number. The four-year-old students were taught using only explicit number names for the entire year. The five-year-old students were taught using explicit number names during the first semester and both explicit and traditional number names during the second semester of the school year. Beauford's study involved a small sample with no control group.

This research extended the study of language differences and the understanding of place value to a quasi-experimental study of a larger sample that included both an experimental and a control group when interventions were utilized. To investigate whether number names affect students' cognitive understanding of place value, this research involved the use of explicit and traditional names of numbers with young children. In examining the influence of language on the cognitive understanding of place value, the following questions involving the components of place-value understanding were examined:

1. Is there a difference in rote counting between children taught with explicit number names and children taught with traditional number names?
2. Is performance in reading two-digit numerals independent of group membership of children taught with explicit number names and children taught with traditional number names?
3. Is performance in modeling two-digit numerals independent of group membership of children taught with explicit number names and children taught with traditional number names?
4. Is accuracy of identifying the place value of the digits of two-digit numerals independent of group membership of children taught with explicit number names and children taught with traditional number names?

Definitions *Place value.* The term place value refers to the value assigned to a digit due to the position of the digit in a numeral. The three elements of place value understanding are: (a) grouping by tens, (b) spoken names of numbers, and (c) written names of numbers (Van de Walle & Lovin, 2006).

Explicit number name. In this study, students were taught to say numbers explicitly. In other words, instead of saying "forty two", the students were taught to say "four tens two". This method of naming numbers accurately indicates the base-10 place value of numbers; therefore this is called the "explicit" method for naming numbers. This is also called base-ten language.

Modeling number. Students were also asked to represent two-digit numbers with straws. Straws bundled into groups of tens to represent the numeral in the tens place were called ten-bundles. Single straws represented the numeral in the ones place.

Canonical representation. A representation of a two-digit number using the correct number of ten-bundles and single straws was defined as a canonical representation (see Figure 1).

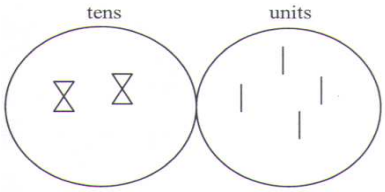

Figure 1. Canonical representations of "24". ⧖ = ten-bundle, | = unit.

Noncanonical representation. A correct representation of a two-digit number that was not canonical was defined as a noncanonical representation. Three possible noncanonical representations were noted (see Figure 2).

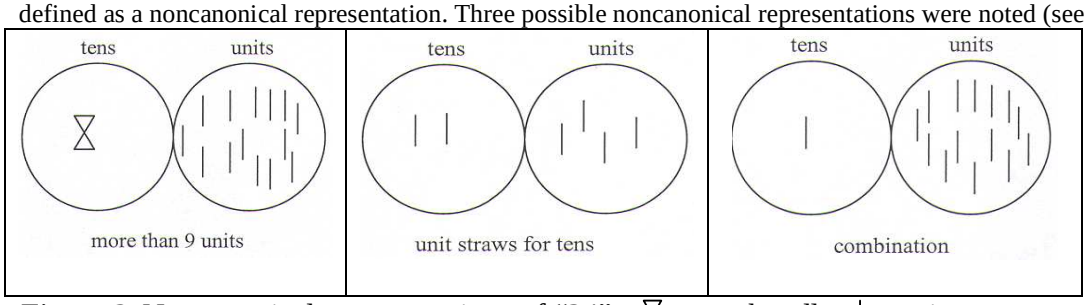

Figure 2. Noncanonical representations of "24". ⧖ = ten-bundle, | = unit.

One-to-one representation. A representation of a two-digit number in which the student uses only single straws with no ten-bundles was defined as a one-to-one (1-1) representation. In a 1-1 representation, the student counted each straw only once as the student represented the given number (see Figure 3).

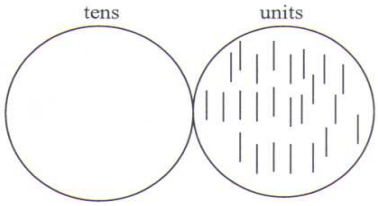

Figure 3. 1-1 representations of "24". ⧖ = ten-bundle, | = unit.

Incorrect representation. A representation of a two-digit number that is completely incorrect due to any other reason was simply called an incorrect representation (see Figure 4).

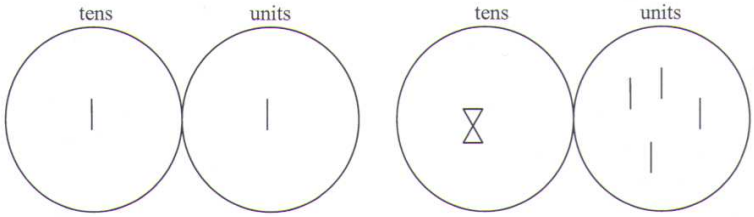

Figure 4. Examples of an incorrect representation of "24". ⧖ = ten-bundle, | = unit.

Research Design This study was a quasi-experiment comparing the performance of students using explicit number

names and the performance of students using traditional number names in demonstrating a cognitive understanding of place value. Three groups of participants were involved in this study. The first group consisted of prekindergarten and kindergarten students. These students were taught to use explicit number names such as "one-ten two" for the quantity "12" and were the treatment group. Spanish-dominant students in the bilingual classes were taught to say "uno dies dos" rather than "doce" for the quantity "12". The second group of prekindergarten and kindergarten students was taught to use traditional number names, such as "twelve" for the quantity "12". This group was the control group. The third group consisted of the teachers of the students in both the control group and the treatment group. Explicit number names were used during the full year of kindergarten and prekindergarten. A pre- and post-assessment of rote counting, reading five two-digit numerals, modeling five two-digit numbers, and identifying the place value of individual digits of two-digit numerals were conducted. The teachers of both the control and treatment groups were interviewed.

Participants. The participants were selected from students enrolled in a small public school district in a south central city. The school district has an enrollment of approximately 500 students per grade level reflecting the diversity of area with 68% Hispanic, 24% Anglo, and 6% African-American. The study involved the three prekindergarten classes, one of which was a bilingual class comprised of students whose first language was Spanish.

Two kindergarten classes from two elementary campuses participated in the study. One elementary campus served predominantly affluent students while the other elementary campus served predominantly low socio-economic students. One of the kindergarten classes on the more affluent campus was a bilingual class comprised of Spanish-dominant students.

A total of 115 students participated in the study with 53 (46%) prekindergarten students and 62 (54%) kindergarten students. The study was comprised of 49% male participants and 51% female participants. The treatment group comprised 57% of the participants, and the control group comprised 43% of the participants.

Data collection. Students in both the treatment group and the control group were individually assessed two times during an eight-month period. Using a script to standardize the interviews, the interviewer asked students to perform four tasks: (a) count as far as they could, (b) read five cards with two-digit numerals on them, (c) model with bundles of ten straws and single straws a different set of two-digit numbers on five cards, and (d) identify the place value of the digits of two-digit numerals for two numerals. Data was collected during each interview using a standardized recording document. In addition to interviewing the students, teacher observations specific to lessons involving the teaching of place value were conducted. The class visits allowed the researcher to: (a) become a familiar face to the children, (b) observe children in the class setting, (c) observe teaching practices, and (d) serve as a resource for teachers.

At least two observations of each teacher were conducted during the study. District personnel requested that the researcher use the district-wide observation form. The teachers were familiar with this form and were, therefore, very comfortable with observations being recorded with this form.

Results

Rote counting. Research question one asked whether children taught to rote count with explicit number names would perform differently from children using traditional number names. From September to May, the treatment group and the control group for both prekindergarten and kindergarten students improved in their ability to rote count. No significant differences were found in the highest number reached when rote counting for prekindergarten students or kindergarten students when taught to use explicit number names rather than traditional number names. However, notable differences in counting errors were found between the kindergarten control and treatment groups. The percentage of minor errors in the treatment group decreased considerably (pre-assessment 20%, post-assessment 3%) while the control group's percentage of minor errors remained constant at 19%.

Reading two-digit numerals. Research question two asked if performance in reading two-digit numbers was independent of group membership for children using explicit number names or children using traditional number names. Performance in reading two-digit numerals was independent of group membership for prekindergarten students on the post-assessment. However, the prekindergarten treatment group read about 30% fewer of the numerals incorrectly than did the control group. On the post-assessment, a significant relationship was found for kindergarten students (χ^2 (3) = 13.99, p < .001) when taught to use explicit number names rather than traditional number names. Approximately 70% of the numerals were read correctly by the treatment group, and approximately 40% of the numerals were read correctly by the control group.

Modeling two-digit numbers. Research question three asked if performance in modeling two-digit numbers was independent of group membership for children using explicit number names or children using traditional number names. For prekindergarten students, performance in modeling two-digit numerals was dependent on group membership (χ^2 (2) = 12.76, p < .01) with the number of canonical representations increasing in the treatment group.

For kindergarten students, performance in modeling two-digit numerals was also dependent on group

membership (χ^2 (3) = 43.90, $p < .001$). The percentage of numbers modeled correctly by the treatment group was about twice that of the control group. Also, the treatment group was able to model 44% of the numbers canonically compared to about 10% of the control group. Notably, the kindergarten control group placed the correct number of ten-bundles and unit straws into the appropriate side of the two-sided container for 7 numbers, and the kindergarten treatment group placed the correct number of ten-bundles and unit straws into the appropriate side of the two-sided container for 62 numbers.

Identifying place value. Research question four asked if performance in identifying the place value of individual digits of two-digit numerals was independent of group membership for children using explicit number names or children using traditional number names. The largest difference in reading numerals occurred when the kindergarten students were asked to point to the tens and ones place of a numeral. A significant dependence was found between group membership and identifying place value (χ^2 (1) = 16.36, $p < .001$). The percentage of correct responses in the treatment group (53%) was approximately twice the percentage of correct responses in the control group (28%). The kindergarten students in the treatment group who correctly identified the place value of a numeral on a card did so with confidence.

Discussion

This study included prekindergarten and kindergarten students since language acquisition is a primary goal for these students. Learning to count, whether using explicit or traditional number names, is part of the process of acquiring language and building vocabulary. The results of this study correspond with Sousa's (2008) observation that American children have trouble counting past ten at age four while most Chinese children can count to 40 by age four. According to Sousa, this difference is due to the simplicity of explicit number names as well as the syntax reinforcing the decimal system resulting in "Chinese speakers [processing] arithmetic manipulation in areas of the brain different from those of native English speakers" (p. 19).

Kindergarten students are still developing an understanding of place value, and the use of explicit number names seems to have had a positive effect on the students' ability to read two-digit numerals as evidenced by the larger percentage of numerals read correctly by the treatment group. According to teacher reports, the students taught explicit number names had fewer digit reversals than did students using traditional number names. The reinforcement of place value in the explicit number names may have allowed students to realize that the position of the digits in a numeral determines the value of the digit.

Unlike reading abstract numerals, modeling numbers with manipulatives is a concrete activity in that the students can see, touch, and physically move the manipulatives. The use of explicit number names, reinforcing place value, coupled with ten-bundles of straws that represent numbers in the tens place and single straws that represent numbers in the ones place may have provided students with the support necessary to connect the position of a digit with the number of ten-bundles or single straws needed to represent the value of the digit.

These findings supported the findings by Alsawaie (2004). Assessing students in first grade, Alsawaie found that 51.2% of the students represented numbers canonically when prompted while 12% of the students represented numbers canonically when not prompted. However, Alsawaie's study assessed the students only once rather than in a pre- and post situation.

Cotter (2000) also studied the use of explicit number names with first grade students. No pre-assessment was administered, but an intervention was utilized with a treatment group for eight months. A control group received no intervention. Cotter's findings that the students' performance in modeling two-digit numbers canonically improved when taught explicit number names were supported in this study.

While conclusions in this study must be tempered by the lack of longitudinal data on the students involved concerning their success in mathematics in subsequent grades, the findings suggest that the use of explicit number names does increase students' performance in reading, modeling, and identifying place value in two-digit numerals. The improvement of the treatment group overall exceeded the improvement of the control group. Pending a longitudinal study, the cautious conclusion is that using explicit number names can increase the understanding of place value of prekindergarten and kindergarten students.

Possibilities for Transfer to Different Environments

Since the beginning of this project in 2003, we have developed strategies and techniques to improve the validity and reliability of assessment of these young children. While the sites involved has proven to be valuable learning laboratories for research strategy, the relatively small size of the study dictates that it can only be considered a beginning for this research. To achieve generalizability will require similar projects in many classes using a variety of teaching styles and curricula so as to negate the effects of any one environment. We are continuing this research in bilingual elementary schools in Saltillo, Mexico, and also in Santa Cruz and Cochabamba, Bolivia.